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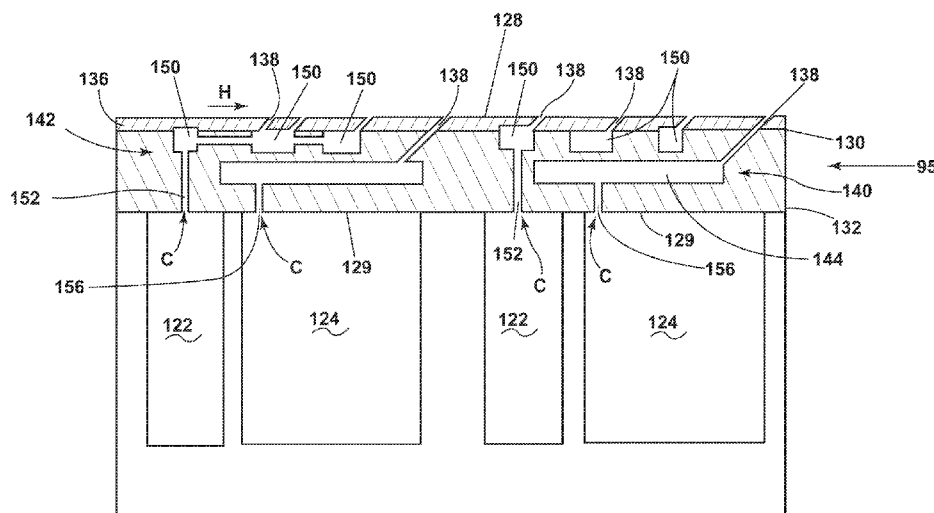


FIG. 5

(57) Abstract: An airfoil for a turbine engine having an engine component including an internal cooling circuit fluidly coupled to a plurality of passages within the outer wall of the engine component where cooling air moves from the internal cooling circuit to an outer surface of the engine component through the passages.

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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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AIRFOIL HAVING A SKIN COOLING CIRCUIT

BACKGROUND OF THE INVENTION

[0001] Turbine engines, and particularly gas or combustion turbine engines, are rotary engines that extract energy from a flow of combusted gases passing through the engine onto a multitude of rotating turbine blades. Turbine engines have been used for land and nautical locomotion and power generation, but are most commonly used for aeronautical applications such as for aircraft, including helicopters. In aircraft, turbine engines are used for propulsion of the aircraft. In terrestrial applications, turbine engines are often used for power generation.

[0002] Turbine engines for aircraft are designed to operate at high temperatures to maximize engine efficiency, so cooling of certain engine components, such as the high pressure turbine and the low pressure turbine, can be beneficial. Typically, cooling is accomplished by ducting cooler air from the high and/or low pressure compressors to the engine components that require cooling. Temperatures in the high pressure turbine are around 1000 °C to 2000 °C and the cooling air from the compressor is around 500 °C to 700 °C. While the compressor air is a high temperature, it is cooler relative to the turbine air, and can be used to cool the turbine.

[0003] Contemporary turbine blades generally include one or more interior cooling circuits for routing the cooling air through the blade to cool different portions of the blade, and can include dedicated cooling circuits for cooling different portions of the blade, such as the leading edge, trailing edge and tip of the blade.

BRIEF DESCRIPTION OF THE INVENTION

[0004] An airfoil for a turbine engine, the airfoil comprising: an outer wall having an outer surface and an inner surface bounding an interior space, the outer wall defining a pressure side and a suction side extending axially between a leading edge and a trailing edge and extending radially between a root and a tip, at least one coating applied to the outer surface; at least one skin cooling circuit comprising at least one channel formed in the outer surface and at least one film hole passing through the coating to the channel, at least one wall cooling passage provided within at least a portion of an interior of the outer wall and at least one film hole passing through the coating and a portion of the interior of

the outer wall to the wall cooling passage; and first and second supply circuits located within the interior of the wall, with the first supply circuit fluidly coupling a first air supply to the at least one channel to define a skin cooling circuit and the second supply circuit fluidly coupling the second air supply to the at least one wall cooling passage to define a wall cooling circuit.

[0005] An engine component for a turbine engine, which generates a hot air flow, and provides a cooling fluid flow, the component comprising: a wall separating the hot air flow from the cooling fluid flow and having a first surface along which the hot air flows in a hot flow path and a second surface facing the cooling fluid flow, at least one coating applied to the first surface, at least one skin cooling circuit comprising at least one channel formed in the first surface and at least one hole passing through the at least one coating to the channel, at least one wall cooling passage provided within at least a portion of an interior of the wall, first and second supply circuits, with the first supply circuit fluidly coupling the cooling fluid flow to the at least one channel to define a skin cooling circuit and the second supply circuit fluidly coupling the cooling fluid flow to the at least one wall cooling passage to define a wall cooling circuit.

[0006] A method of cooling an airfoil comprising passing a cooling airflow from a source in parallel to a) an interior of an outer wall of an airfoil to form a wall cooling circuit, and b) to a channel in an outer surface of the outer wall, and then to a hole in a coating overlying the outer surface to form a skin cooling circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the drawings:

[0008] Figure 1 is a schematic cross-sectional diagram of a turbine engine for an aircraft.

[0009] Figure 2 is a perspective view of an engine component in the form of a turbine blade of the engine of Figure 1 with cooling air inlet passages.

[0010] Figure 3 is a schematic peripheral view of the airfoil of Figure 2.

[0011] Figure 4 is a cross sectional view of the airfoil of Figure 2 and illustrating a plurality of internal passages.

[0012] Figure 5 is a schematic representation of a call out portion of the airfoil of Figure 4 illustrating a wall cooling circuit, a skin cooling circuit, and an air supply circuit.

[0013] Figure 6 is an enlarged view of a portion of the airfoil from Figure 5 illustrating flow air supply paths.

[0014] Figure 7A and 7B are enlarged view of a portion of the airfoil from Figure 5 illustrating flow directions.

[0015] Figure 8A, 8B, and 8C are additional enlarged views of a portion of the airfoil from Figure 5 illustrating different paths of the flow directions from Figure 6.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0016] The described embodiments of the present invention are directed to an engine component for an engine having a cooling circuit comprising skin cooling circuits and wall cooling passages each separately coupled to an internal passage or supply circuit within for example an airfoil to cool an outer surface of the airfoil. For purposes of illustration, the present invention will be described with respect to the turbine for an aircraft gas turbine engine. It will be understood, however, that the invention is not so limited and may have general applicability within an engine, including compressors, as well as in non-aircraft applications, such as other mobile applications and non-mobile industrial, commercial, and residential applications.

[0017] As used herein, the term “forward” or “upstream” refers to moving in a direction toward the engine inlet, or a component being relatively closer to the engine inlet as compared to another component. The term “aft” or “downstream” used in conjunction with “forward” or “upstream” refers to a direction toward the rear or outlet of the engine or being relatively closer to the engine outlet as compared to another component.

[0018] Additionally, as used herein, the terms “radial” or “radially” refer to a dimension extending between a center longitudinal axis of the engine and an outer engine circumference.

[0019] All directional references (e.g., radial, axial, proximal, distal, upper, lower, upward, downward, left, right, lateral, front, back, top, bottom, above, below, vertical, horizontal, clockwise, counterclockwise, upstream, downstream, forward, aft, etc.) are only used for identification purposes to aid the reader’s understanding of the present invention, and do not create limitations, particularly as to the position, orientation, or use of the invention. Connection references (e.g., attached, coupled, connected, and joined) are to be construed broadly and can include intermediate members between a collection

of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to one another. The exemplary drawings are for purposes of illustration only and the dimensions, positions, order and relative sizes reflected in the drawings attached hereto can vary.

[0020] FIG. 1 is a schematic cross-sectional diagram of a turbine engine 10 for an aircraft. The engine 10 has a generally longitudinally extending axis or centerline 12 extending forward 14 to aft 16. The engine 10 includes, in downstream serial flow relationship, a fan section 18 including a fan 20, a compressor section 22 including a booster or low pressure (LP) compressor 24 and a high pressure (HP) compressor 26, a combustion section 28 including a combustor 30, a turbine section 32 including a HP turbine 34, and a LP turbine 36, and an exhaust section 38.

[0021] The fan section 18 includes a fan casing 40 surrounding the fan 20. The fan 20 includes a plurality of fan blades 42 disposed radially about the centerline 12. The HP compressor 26, the combustor 30, and the HP turbine 34 form a core 44 of the engine 10, which generates a hot air flow. The core 44 is surrounded by core casing 46, which can be coupled with the fan casing 40.

[0022] A HP shaft or spool 48 disposed coaxially about the centerline 12 of the engine 10 drivingly connects the HP turbine 34 to the HP compressor 26. A LP shaft or spool 50, which is disposed coaxially about the centerline 12 of the engine 10 within the larger diameter annular HP spool 48, drivingly connects the LP turbine 36 to the LP compressor 24 and fan 20. The spools 48, 50 are rotatable about the engine centerline and couple to a plurality of rotatable elements, which can collectively define a rotor 51.

[0023] The LP compressor 24 and the HP compressor 26 respectively include a plurality of compressor stages 52, 54, in which a set of compressor blades 56, 58 rotate relative to a corresponding set of static compressor vanes 60, 62 (also called a nozzle) to compress or pressurize the stream of fluid passing through the stage. In a single compressor stage 52, 54, multiple compressor blades 56, 58 can be provided in a ring and can extend radially outwardly relative to the centerline 12, from a blade platform to a blade tip, while the corresponding static compressor vanes 60, 62 are positioned upstream of and adjacent to the rotating blades 56, 58. It is noted that the number of blades, vanes,

and compressor stages shown in FIG. 1 were selected for illustrative purposes only, and that other numbers are possible.

[0024] The blades 56, 58 for a stage of the compressor can be mounted to a disk 61, which is mounted to the corresponding one of the HP and LP spools 48, 50, with each stage having its own disk 61. The vanes 60, 62 for a stage of the compressor can be mounted to the core casing 46 in a circumferential arrangement.

[0025] The HP turbine 34 and the LP turbine 36 respectively include a plurality of turbine stages 64, 66, in which a set of turbine blades 68, 70 are rotated relative to a corresponding set of static turbine vanes 72, 74 (also called a nozzle) to extract energy from the stream of fluid passing through the stage. In a single turbine stage 64, 66, multiple turbine blades 68, 70 can be provided in a ring and can extend radially outwardly relative to the centerline 12, from a blade platform to a blade tip, while the corresponding static turbine vanes 72, 74 are positioned upstream of and adjacent to the rotating blades 68, 70. It is noted that the number of blades, vanes, and turbine stages shown in FIG. 1 were selected for illustrative purposes only, and that other numbers are possible.

[0026] The blades 68, 70 for a stage of the turbine can be mounted to a disk 71, which is mounted to the corresponding one of the HP and LP spools 48, 50, with each stage having a dedicated disk 71. The vanes 72, 74 for a stage of the compressor can be mounted to the core casing 46 in a circumferential arrangement.

[0027] Complementary to the rotor portion, the stationary portions of the engine 10, such as the static vanes 60, 62, 72, 74 among the compressor and turbine section 22, 32 are also referred to individually or collectively as a stator 63. As such, the stator 63 can refer to the combination of non-rotating elements throughout the engine 10.

[0028] In operation, the air flow exiting the fan section 18 is split such that a portion of the air flow is channeled into the LP compressor 24, which then supplies pressurized air 76 to the HP compressor 26, which further pressurizes the air. The pressurized air 76 from the HP compressor 26 is mixed with fuel in the combustor 30 and ignited, thereby generating combustion gases. Some work is extracted from these gases by the HP turbine 34, which drives the HP compressor 26. The combustion gases are discharged into the LP turbine 36, which extracts additional work to drive the LP compressor 24, and the exhaust gas is ultimately discharged from the engine 10 via the exhaust section 38. The driving of the LP turbine 36 drives the LP spool 50 to rotate the fan 20 and the LP compressor 24.

[0029] A portion of the pressurized air flow 76 can be drawn from the compressor section 22 as bleed air 77. The bleed air 77 can be draw from the pressurized air flow 76 and provided to engine components requiring cooling. The temperature of pressurized air flow 76 entering the combustor 30 is significantly increased. As such, cooling provided by the bleed air 77 is necessary for operating of such engine components in the heightened temperature environments.

[0030] A remaining portion of the air flow 78 bypasses the LP compressor 24 and engine core 44 and exits the engine assembly 10 through a stationary vane row, and more particularly an outlet guide vane assembly 80, comprising a plurality of airfoil guide vanes 82, at the fan exhaust side 84. More specifically, a circumferential row of radially extending airfoil guide vanes 82 are utilized adjacent the fan section 18 to exert some directional control of the air flow 78.

[0031] Some of the air supplied by the fan 20 can bypass the engine core 44 and be used for cooling of portions, especially hot portions, of the engine 10, and/or used to cool or power other aspects of the aircraft. In the context of a turbine engine, the hot portions of the engine are normally downstream of the combustor 30, especially the turbine section 32, with the HP turbine 34 being the hottest portion as it is directly downstream of the combustion section 28. Other sources of cooling fluid can be, but are not limited to, fluid discharged from the LP compressor 24 or the HP compressor 26.

[0032] Figure 2 is a perspective view of an engine component in the form of one of the turbine blades 68 of the engine 10 from Figure 1. The turbine blade 68 includes a dovetail 79 and an airfoil 79. The airfoil 79 extends radially between a root 83 and a tip 81. The dovetail 79 further includes a platform 84 integral with the airfoil 79 at the root 83, which helps to radially contain the turbine air flow. The dovetail 79 can be configured to mount to a turbine rotor disk on the engine 10. The dovetail 79 comprises at least one inlet passage, exemplarily shown as a first inlet passage 88, a second inlet passage 90, and a third inlet passage 92, each extending through the dovetail 79 to provide internal fluid communication with the airfoil 79 at a passage outlet 94. It should be appreciated that the dovetail 79 is shown in cross-section, such that the inlet passages 88, 90, 92 are housed within the body of the dovetail 79.

[0033] Turning to Figure 3, the airfoil 79, shown in cross-section, comprises an outer wall 95 bounding an interior space 96 having a concave-shaped pressure side 98 and a

convex-shaped suction side 100 which are joined together to define an airfoil shape extending axially between a leading edge 102 and a trailing edge 104. The blade 68 rotates in a direction such that the pressure side 98 follows the suction side 100. Thus, as shown in Figure 3, the airfoil 79 would rotate upward toward the top of the page.

[0034] Referring to Figure 4, the interior space 96 can be divided into a plurality of internal cooling air supply circuits 122, 124, 126 which can be arranged in any formation within the interior space 96 and are dedicated to supply cooling air to the interior space 96. The supply circuits are fluidly coupled to at least one of the inlet passages 88, 90, 92 where internal fluid communication is provided to at least one of the supply circuits through the passage outlet 94.

[0035] It should be appreciated that the respective geometries of each individual supply circuit within the airfoil 79 as shown is exemplary, and not meant to limit the airfoil to the number of supply circuits, their geometries, dimensions, or positions as shown.

Additionally the supply circuits 122, 124, 126 can be fluidly coupled to each other to provide additional internal fluid communication between adjacent supply circuits.

Further, while three supply circuits are shown, there can be any number of supply circuits from none, to one, to multiple, for example.

[0036] The outer wall 95 comprises an outer surface 130 and an inner surface 132, which defines an interior 134 that is generally solid. At least one coating 136 is applied to the outer surface 130 where the coating 136 can include one or more layers comprising metallic, ceramic, or any other suitable material. The outer surface 130 and the at least one coating define a “skin” for the airfoil. The outer wall 95, including the skin, separates a hot air flow H on a first surface 128 of the airfoil from a cooling fluid flow C along a second surface 129 and supplied to the supply circuits 122, 124, 126. The coating 136 can be formed by various known methods such as spray, vapor deposition, and so forth, and also by additive manufacturing.

[0037] A plurality of film holes 138 can be provided through the surface of the outer wall 95 to provide cooling air onto the exterior of the airfoil 79. A wall cooling circuit 140 and a skin cooling circuit 142 are provided with the airfoil 79 and can each be fluidly connected to one of the plurality of film holes 138 to cool the outer wall 95 and the skin 130, 136. It should be understood that film holes can be film cooling exits of any geometry, such as but not limited to holes, shaped holes, and slots.

[0038] It can be contemplated that the skin cooling circuit 142 and wall cooling circuit 140 can be multiple skin and wall cooling circuits 142, 140 and that at least some of the skin and wall cooling circuits 140, 142 are fluidly coupled to multiple supply circuits and circumscribe a portion of or the entire airfoil interior 96. Though three supply circuits are illustrated, more or less supply circuits can be located within the airfoil interior 96.

[0039] Referring to Figure 5, the details of the wall cooling circuit 140 and the skin cooling circuit 142 will be described with respect to this schematic representation of a portion of the airfoil Figure 4. The skin cooling circuit 142 comprises at least one channel 150 provided in the outer surface 130 and at least one film hole 138 passing through the coating 136 to the channel 150. The skin cooling circuit 142 can be formed in the outer surface 130 or in the coating 136 or formed in a combination of both as illustrated. In some embodiments, a portion of the coating 136 shown could be part of the same substrate that forms the channels 150, and then a coating added on top, enclosing the skin cooling circuit 142 with a non-coating material for example with a metal plate that is brazed on or attached to the outer surface. It should be understood that the multiple channels and passages shown are exemplary and not meant to be limiting for example in shape, orientation, or size.

[0040] The at least one channel 150 can be multiple channels 150, which are fluidly coupled to each other or fluidly separate from each other. The multiple channels 150 may be arranged in groups, which can be used to form sub-circuits within the skin cooling circuit 142. The multiple channels 150 can vary in width and length. It is further contemplated that multiple film holes 138 can pass through the coating to only one of the multiple channels 150 or to several or all of the multiple channels 150. It can be contemplated that the channels 150 can be of the same or less dimensions as the wall cooling passages 144, and in further embodiments are 50% or less of the wall cooling passages 144.

[0041] The skin cooling circuit 142 is fluidly coupled to a first supply circuit 122 located within the interior space 96 of the airfoil 79. The first supply circuit 122 is fluidly coupled to at least one of the channels 150 through at least one internal hole 152 that can be formed as an aperture or slot.

[0042] The wall cooling circuit 140 comprises one or more wall cooling passages 144 provided within the interior 134 of the wall 95 and bounded by the outer and inner

surfaces 130, 132 and at least one film hole 138 passing through the coating 136 and the interior 134 to the wall cooling passage 144. It is further contemplated that multiple film holes 138 can pass through the coating to the wall cooling passage 144.

[0043] A second supply circuit 124 located within the interior space 96 of the airfoil 79 is fluidly coupled to at least one of the wall cooling passages 144 through another at least one internal hole 156. The wall cooling circuit 140 including the second supply circuit 124 and the wall cooling passage 144 are fluidly separate from the skin cooling circuit 142. The first and second supply circuits 122, 124 can supply cooling air as needed which can be the same or different types of cooling air. The wall cooling circuit 140 and the skin cooling circuit 142 can alternately be supplied from the same supply circuit (e.g. 124) wherein the one supply circuit 124 is fluidly coupled to both a channel 150 and a wall cooling passage 144.

[0044] Turning now to Figure 6, a conditioned air is supplied to both the first and second supply circuits 122, 124 via, for example, one of the first, second, or third inlet passages 88, 90, 92. The conditioned air can be the same or differently conditioned for each of one of the supply circuits 122, 124. At least one of the conditioned air is cooling air wherein a cooling fluid flow C is provided to the first and second supply circuits 122, 124. By conditioned, it is meant that the air supplies can have different characteristics, like pressure and temperature, for example.

[0045] The skin cooling circuit 142 defines a path for conditioned air to flow as a first air supply 160 from the first supply circuit 122, through the channels 150, and exit via the film holes 138. The wall cooling circuit 140 defines a path for conditioned air to flow as a second air supply 162 from the second supply circuit 124, through the wall passages 144, and exit via the film holes 138. The first and second air supplies 160, 162 flow parallel to each other during operation.

[0046] While numerous flow paths are possible with the geometry of the configuration described herein, two possible flow paths are illustrated in Figures 7A and 7B. These flow paths are for illustrative purposes only and are not meant to be limiting.

[0047] Turning to Figure 7A, when conditioned air is supplied to the supply circuits 122, 124, pressure differences between the supply circuits 122, 124 and adjacent channels 150 and wall passages 140 cause the cooling air to move from the supply circuits 122,

124 in a first flow direction SC defined by the supply circuits 122, 124 where the cooling fluid flow C passes through the internal holes 152, 156.

[0048] A second flow direction SCC is dependent on the pressure differentiations between one of the multiple channels 150 and the first supply circuit 122 along with placement of the film holes 138 and the internal hole 152. A third flow direction WCP can flow in the same direction as the second flow direction SCC along the wall passages 140 creating a co-flow in which cooling air runs parallel with and in the same direction as corresponding cooling air in adjacent circuits. This direction is also dependent on pressure differentiations, in this case between the wall cooling passages 140 and the second supply circuit 124, and placement of the film holes 138 and the internal hole 156.

[0049] Turning to Figure 7B, the placement of film holes and the internal holes 152 and 156 in addition to the pressure differentiations present between adjacent cooling circuits can also cause the second flow direction SCC and the third flow direction WCP to be opposite of each other creating a counter-flow in which cooling air runs parallel with and in the opposite direction as corresponding cooling air in adjacent circuits.

[0050] It can be seen that a plurality of orientations can be contemplated regarding the geometry of the skin cooling circuit 142 relative to the wall cooling passages 144. Some of the orientations are shown in Figures 8A, 8B, and 8C. While three different possible orientations are contemplated, it should be understood that they are for illustrative purposes only and are not meant to be limiting. Figure 8A depicts a relative geometry wherein channels 250 run perpendicular to wall passages 244. Figure 8B illustrates a relative geometry wherein channels 350 and wall passages 344 run parallel to each other. Furthermore, Figure 8C shows a relative orientation wherein channels 450 and wall passages 444 run at an angled orientation between the geometries depicted in Figures 8A and 8B.

[0051] Wall cooling circuits 140 and skin cooling circuits 142 can co-flow, counter-flow, or flow at any straight or arcuate intermediate angles with respect to each other, as long as each layer of cooling is retained within its corresponding circuit.

[0052] A method of cooling the airfoil 79 comprises first passing a cooling airflow C from a source, for example the supply circuit 124, in parallel to the wall cooling passage 144 in the interior 134 of the outer wall 95 of an airfoil 79 to form a wall cooling circuit 140 while simultaneously passing a cooling airflow from a separate source in parallel to

the channel 150 in the outer surface 130 of the outer wall 95, and then to a film hole 38 in a coating overlying the outer surface 130 to form a skin cooling circuit 142.

[0053] The passing of the cooling airflow through the skin cooling circuit can be a first direction SCC and the passing of the cooling airflow through the wall cooling circuit can be a second direction WCP wherein the first direction and second directions are the same, different, or opposite as described herein.

[0054] It can be contemplated that an entire engine component with multiple wall passages and skin cooling circuits can be cast as a single piece after which molding and reforming portions of the engine component can be implemented and then a coating applied. Additive manufacturing where a main component such as the supply circuit is cast and the additional components including the wall passages, fluidly connecting holes, and skin cooling circuits are added can also be contemplated.

[0055] The disclosure herein consists of cooled components that utilize both wall cooling circuits and skin cooling circuits flowing in parallel and separate sub-circuits, in which the wall cooling circuits are fed from a different source than the skin cooling circuits.

Skin cooling circuits alone can allow up to 30% cooling flow reduction.

[0056] Benefits to utilizing wall cooling circuits in parallel with skin cooling circuits include increasing thermal uniformity of the substrate structure. In the event that the more at risk skin cooling circuit fails, the parallel wall cooling circuit can still provide thermal and structural integrity to the engine component.

[0057] In newer generation turbine cooling 30 to 50% less flow is utilized as compared to prior turbine cooling. Combining the wall cooling circuit with skin cooling circuits enables 30% cooling flow reduction, decreases cost, and decreases specific fuel consumption.

[0058] This written description uses examples to disclose the invention, including the best mode, and to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and can include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal

language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

CLAIMS

What is claimed is:

1. An airfoil for a turbine engine, the airfoil comprising:
 - an outer wall having an outer surface and an inner surface bounding an interior space, the outer wall defining a pressure side and a suction side extending axially between a leading edge and a trailing edge and extending radially between a root and a tip;
 - at least one coating applied to the outer surface;
 - at least one skin cooling circuit comprising at least one channel formed in the outer surface and at least one film hole passing through the coating to the channel;
 - at least one wall cooling passage provided within at least a portion of an interior of the outer wall and at least one film hole passing through the coating and a portion of the interior of the outer wall to the wall cooling passage; and
 - first and second supply circuits located within the interior of the wall, with the first supply circuit fluidly coupling a first air supply to the at least one channel to define a skin cooling circuit and a second supply circuit fluidly coupling the second air supply to the at least one wall cooling passage to define a wall cooling circuit.
2. The airfoil of claim 1 wherein the first and second air supplies supply the same conditioned air.
3. The airfoil of claim 2 wherein the same conditioned air is cooling air.
4. The airfoil of claim 3 wherein the first and second air supply are the same supply circuit.
5. The airfoil of claim 1 wherein the first and second air supplies supply differently conditioned air.
6. The airfoil of claim 5 wherein the differently conditioned air comprises at least one cooling air supply.
7. The airfoil of claim 1 wherein the skin cooling circuit and wall cooling circuit are operated in parallel.

8. The airfoil of claim 1 further comprising multiple skin cooling circuits.
9. The airfoil of claim 1 further comprising multiple wall cooling circuits.
10. The airfoil of claim 9 further comprising multiple skin cooling circuits.
11. The airfoil of claim 1 wherein the at least one channel comprises multiple channels.
12. The airfoil of claim 11 further comprising multiple film holes for each of the multiple channels.
13. The airfoil of claim 1 wherein the supply circuits define a first flow direction, the channel defines a second flow direction, and the wall cooling passage defines a third flow direction.
14. The airfoil of claim 13 wherein at least two of the first, second and third flow directions are the same.
15. The airfoil of claim 14 wherein second and third flow directions are the same.
16. The airfoil of claim 13 wherein at least two of the first, second and third flow directions are opposite.
17. The airfoil of claim 16 wherein second and third flow directions are opposite.
18. The airfoil of claim 1 wherein the at least one coating comprises multiple coatings.
19. An engine component for a turbine engine, which generates a hot air flow, and provides a cooling fluid flow, the component comprising:
 - a wall separating the hot air flow from the cooling fluid flow and having a first surface along with the hot air flow in a hot flow path and a second surface facing the cooling fluid flow;
 - at least one coating applied to the first surface;
 - at least one skin cooling circuit comprising at least one channel formed in the first surface and at least one hole passing through the at least one coating to the channel;

at least one wall cooling passage provided within at least a portion of an interior of the wall;

first and second supply circuits, with the first supply circuit fluidly coupling the cooling fluid flow to the at least one channel to define a skin cooling circuit and the second supply circuit fluidly coupling the cooling fluid flow to the at least one wall cooling passage to define a wall cooling circuit.

20. The engine component of claim 19 wherein the skin cooling circuit and wall cooling circuit are operated in parallel.
21. The engine component of claim 19 further comprising multiple skin cooling circuits.
22. The engine component of claim 19 further comprising multiple wall cooling circuits.
23. The engine component of claim 22 further comprising multiple skin cooling circuits.
24. The engine component of claim 19 wherein the at least one channel further comprising multiple channels.
25. The engine component of claim 24 further comprising multiple film holes for each of the multiple channels.
26. The engine component of claim 19 wherein supply circuits define a first flow direction, the channel defines a second flow direction, and the wall cooling passage defines a third flow direction.
27. The engine component of claim 26 wherein at least two of the first, second and third flow directions are the same.
28. The engine component of claim 27 wherein second and third flow directions are the same.
29. The engine component of claim 26 wherein at least two of the first, second and third flow directions are opposite.

30. The engine component of claim 29 wherein second and third flow directions are opposite.
31. The engine component of claim 19 wherein the at least one coating comprises multiple coatings.
32. A method of cooling an engine component comprising passing a cooling airflow from a source in parallel to a) a wall passage in an interior of an outer wall of an airfoil, and then to a film hole in a coating overlying an outer surface of the airfoil to form a wall cooling circuit, and b) to a channel in an outer surface of the outer wall, and then to a film hole in a coating overlying the outer surface to form a skin cooling circuit.
33. The method of claim 32 wherein the passing of the cooling air through the skin cooling circuit is in a first direction and the passing of cooling air in the wall cooling circuit is in a second direction.
34. The method of claim 33 wherein the first and second directions are the same.
35. The method of claim 33 wherein the first and second directions are different.
36. The method of claim 35 wherein the first and second directions are opposite.

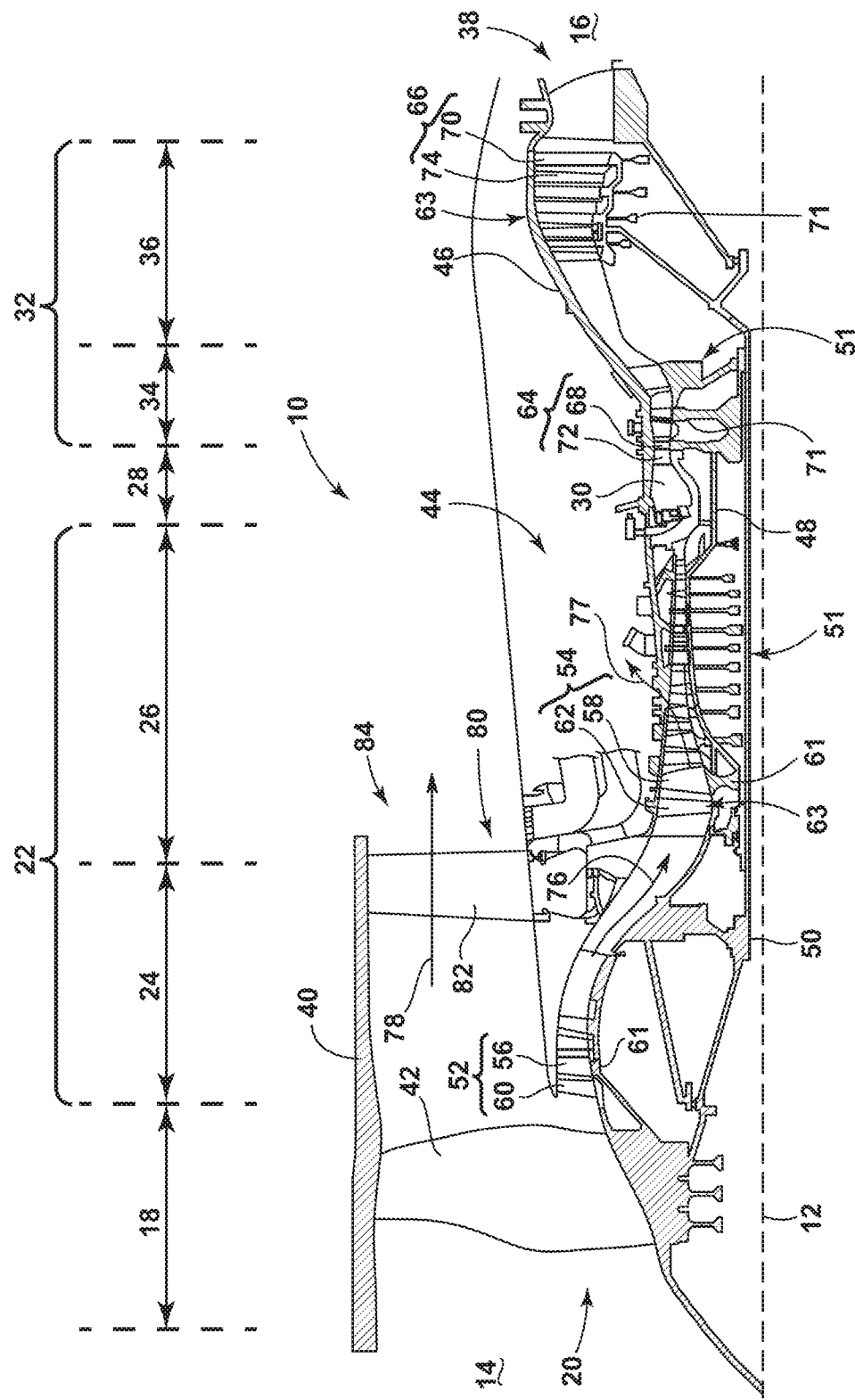


FIG. 1

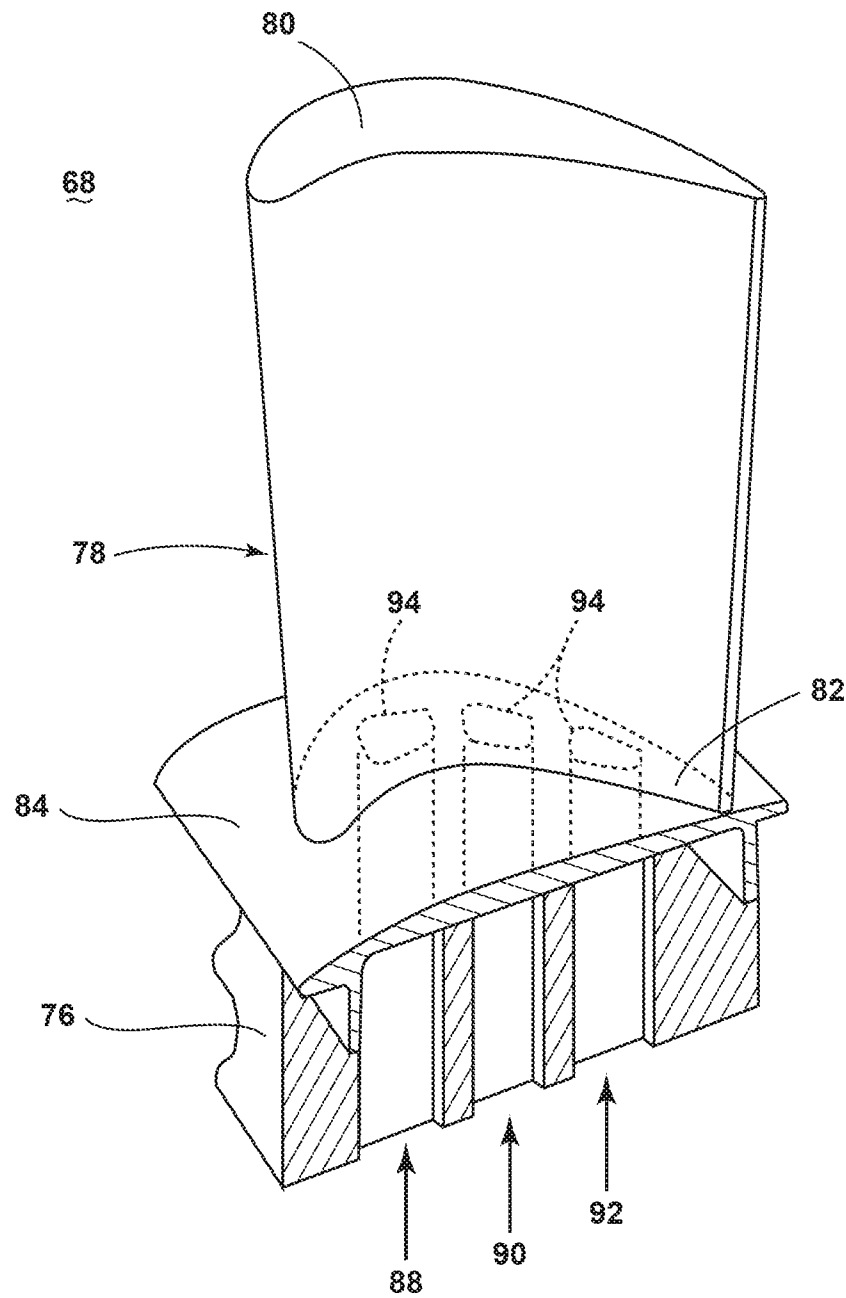
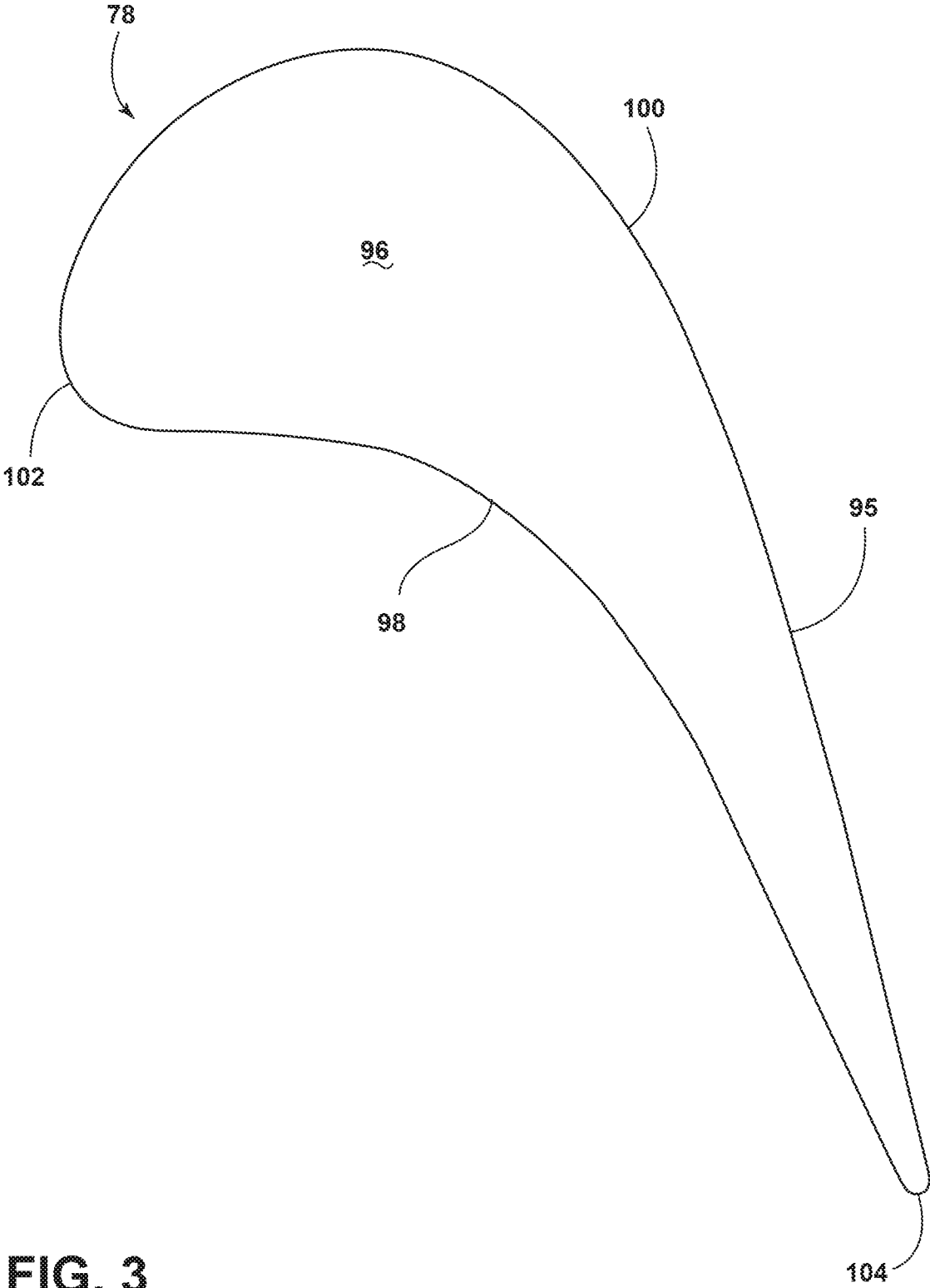


FIG. 2



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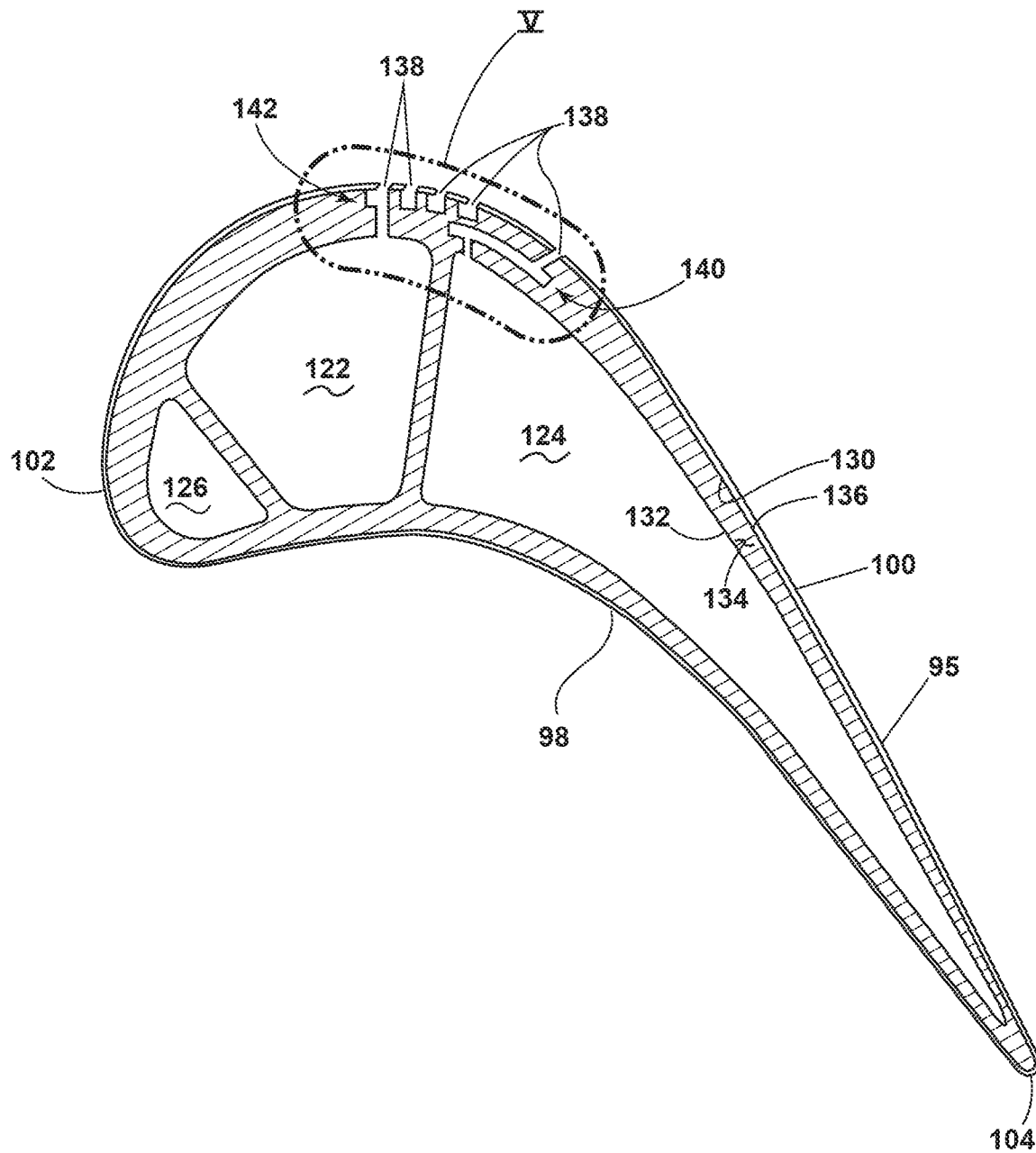
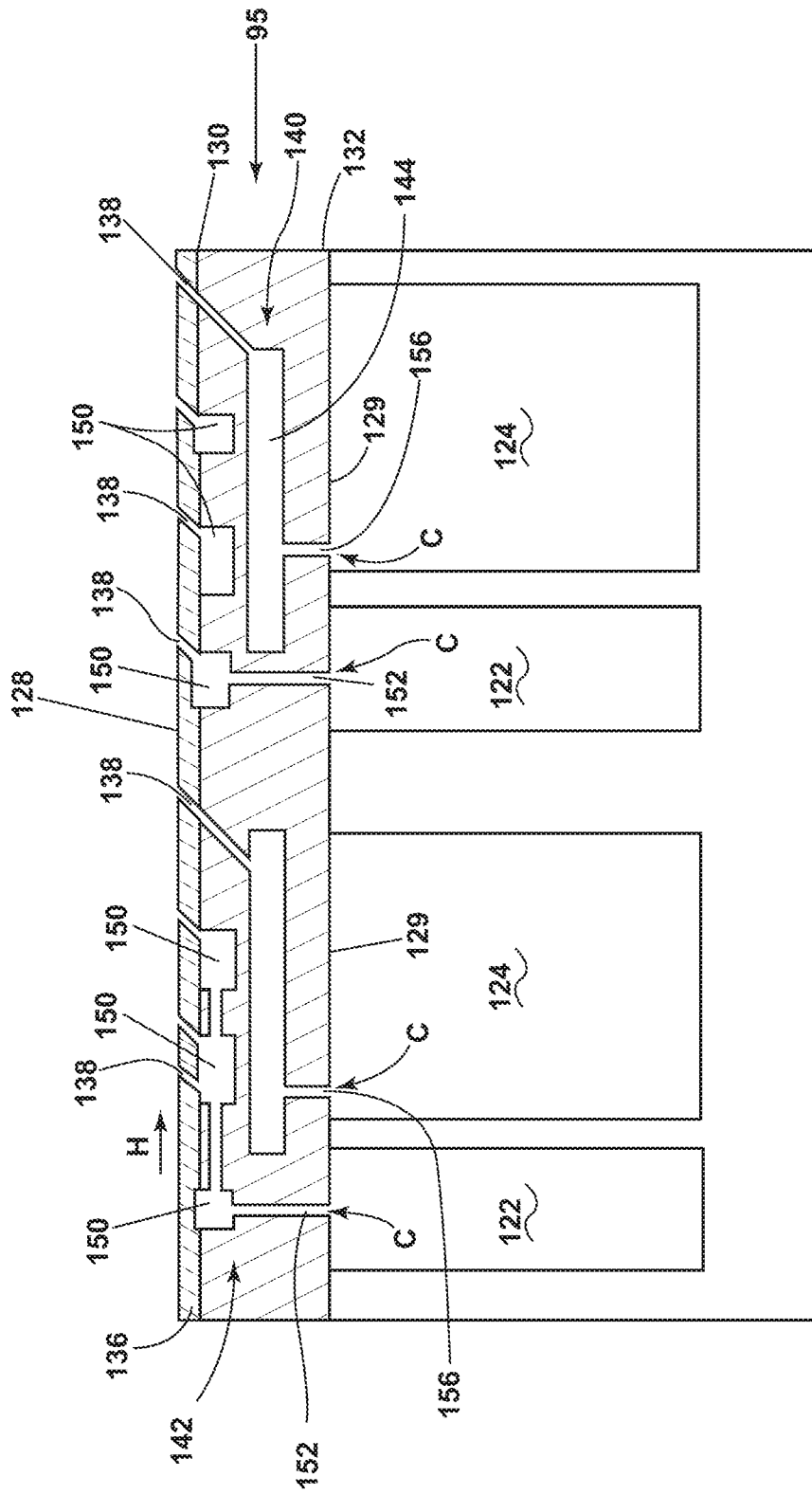
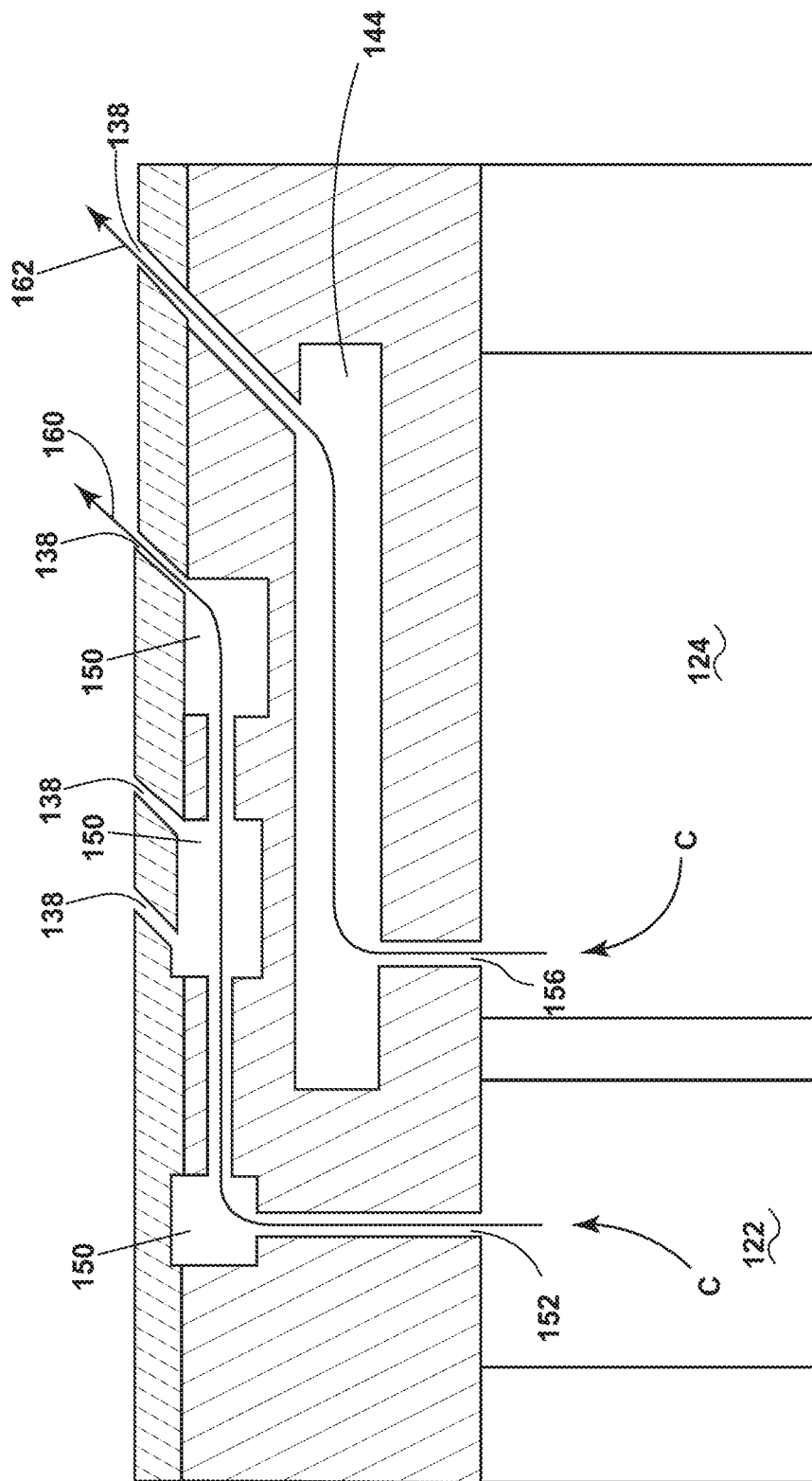


FIG. 4



COLL

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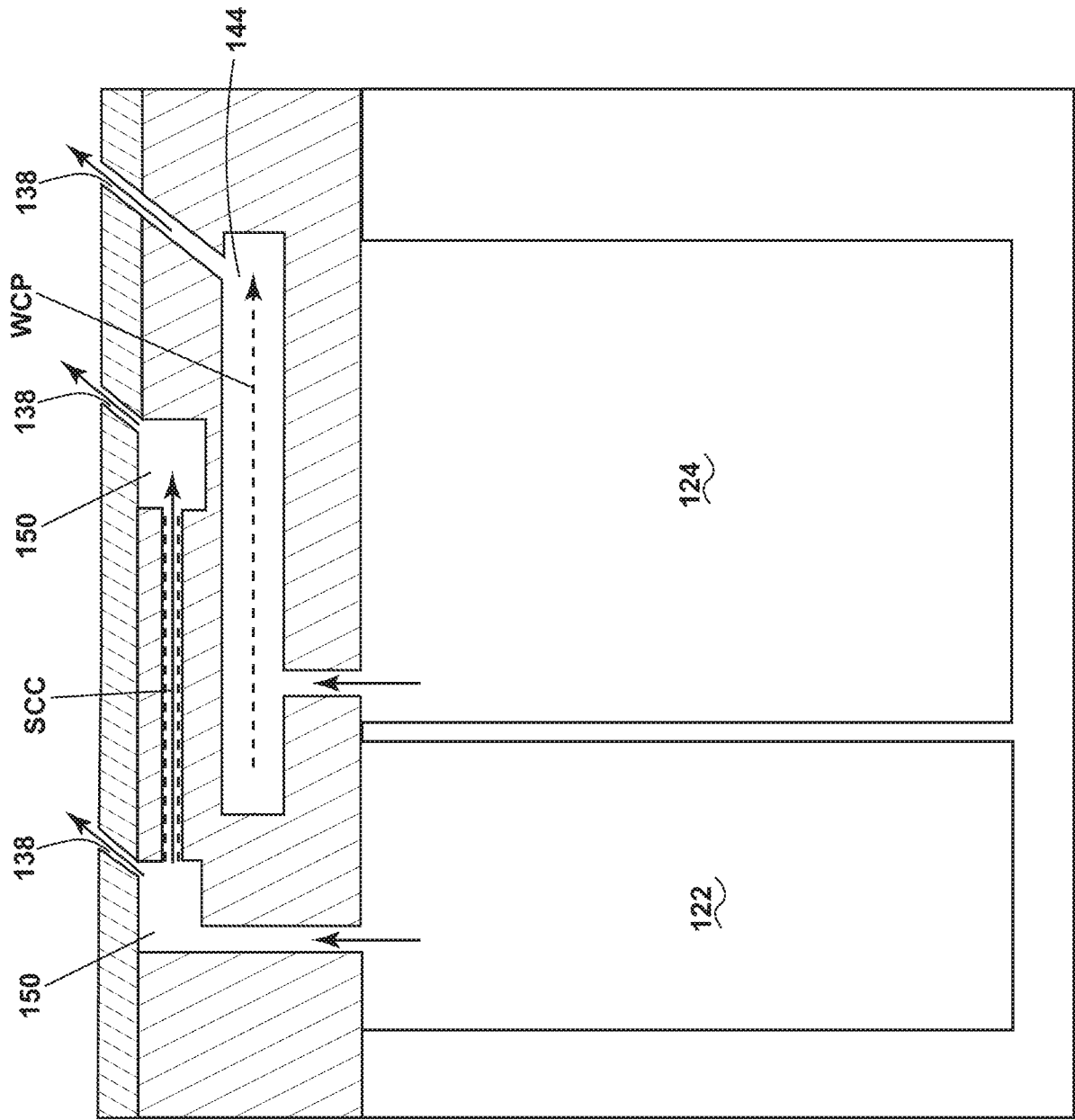


FIG. 7A

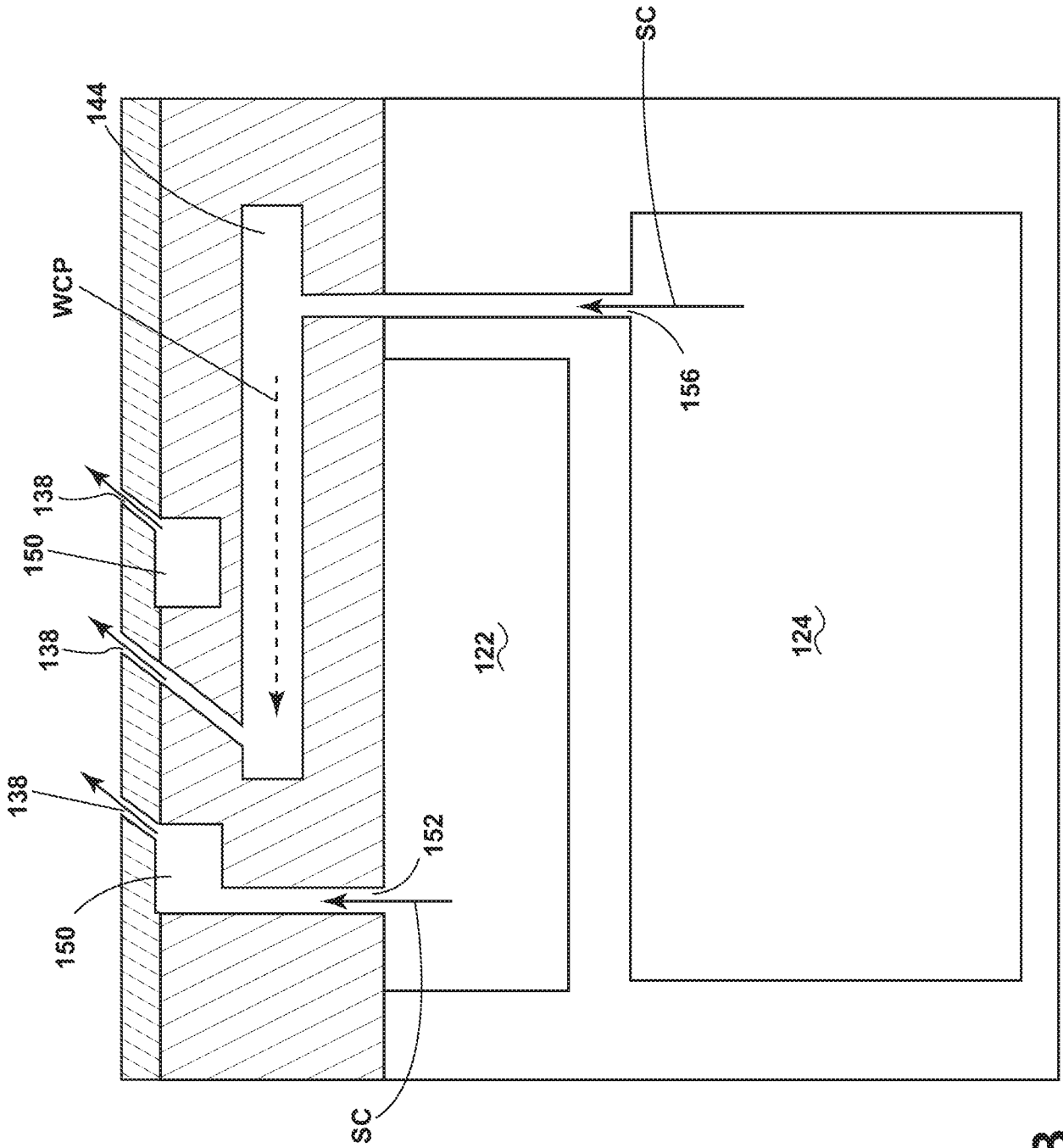


FIG. 7B

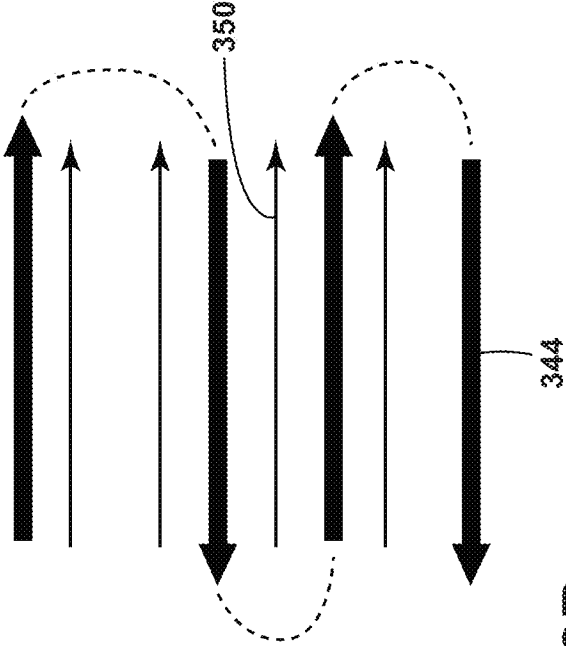


FIG. 8B

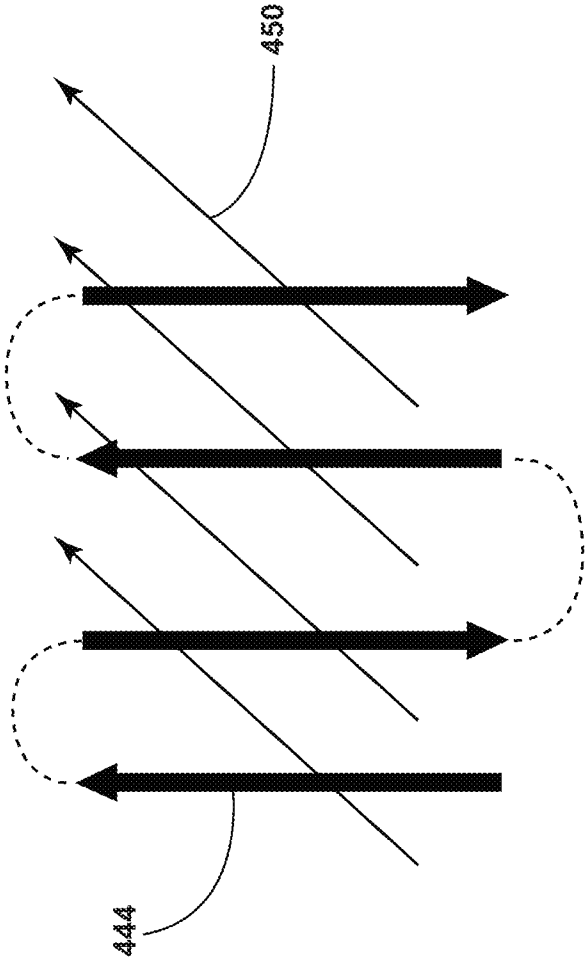


FIG. 8C

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/031494

A. CLASSIFICATION OF SUBJECT MATTER

INV. F01D5/18 F01D5/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/280832 A1 (LIANG GEORGE [US]) 6 December 2007 (2007-12-06) paragraphs [0021] - [0029] figures 2-4 -----	1-36
X	US 7 766 617 B1 (LIANG GEORGE [US]) 3 August 2010 (2010-08-03) columns 2,3 figures 1-4 -----	1-15, 18-28, 31-35
X	US 2014/004310 A1 (REBAK RAUL BASILIO [US] ET AL) 2 January 2014 (2014-01-02) the whole document -----	1-36
X	US 2013/272850 A1 (BUNKER RONALD SCOTT [US]) 17 October 2013 (2013-10-17) figure 3 paragraphs [0037] - [0046] -----	1-36



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See patent family annex.

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Date of the actual completion of the international search

6 July 2017

Date of mailing of the international search report

17/07/2017

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de la Loma, Andrés

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/031494

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